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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U S APPLICATION NO (If known, see 37 CFR 1 5) **10/018369**

INTERNATIONAL APPLICATION NO. PCT/JP00/04071	INTERNATIONAL FILING DATE June 21, 2000	PRIORITY DATE CLAIMED June 22, 1999

TITLE OF INVENTION

METHOD FOR MANUFACTURING AN OPTICAL FIBER PREFORM

APPLICANT(S) FOR DO/EO/US

Hideaki ITO, Masataka KON, Takaharu KINOSHITA, Nobusada NAGAE

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to promptly begin national examination procedures (35 U.S.C. 371(f)).
4. ☒ The US has been elected by the expiration of 19 months from the priority date (PCT Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)).
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.

12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.

13. ☐ A FIRST preliminary amendment.

14. ☐ A SECOND or SUBSEQUENT preliminary amendment.

15. ☐ A substitute specification.

16. ☐ A change of power of attorney and/or address letter.

17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.

18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).

19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).

20. ☒ Other items or information:
   Application Data Sheet
   International Preliminary Examination Report
   Sixteen pages of Formal Drawings (Figs. 1-16)

U.S. APPLICATION NO (If known, see 37 C F R. 1 50)	INTERNATIONAL APPLICATION NO	ATTORNEYS DOCKET NUMBER
10/018369	PCT/JP00/04071	740819-715

	CALCULATIONS	PTO USE ONLY
21. ☒ The following fees are submitted: **BASIC NATIONAL FEE (37 CFR 1.492(a)(1) – (5)):** Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO.................. $1040.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO.............. $890.00 International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(3)) paid to USPTO .... $740.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) but all claims did not satisfy provisions of PCT Article 33(1)-(4)..................... $710.00 International preliminary examination fee paid to USPTO (37 CFR 1.482) and all claims satisfied provisions of PCT Article 33(1)-(4) $100.00	$890.00	

ENTER APPROPRIATE BASIC FEE AMOUNT =	$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	10 - 20 =	0	X $18.00	$	
Independent claims	2 - 3 =	0	X $84.00	$	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ $280.00	$280.00	

TOTAL OF ABOVE CALCULATIONS =	$1,170.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.	$	
SUBTOTAL =	$1,170.00	
Processing fee of $130.00 for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)). +	$	
TOTAL NATIONAL FEE =	$1,170.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). $40.00 per property +	$40.00	
TOTAL FEES ENCLOSED =	$1,210.00	

	Amount to be refunded:	$
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a. ☒ A check in the amount of $1,210.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. _____ in the amount of $_____ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 19-2380 . A duplicate copy of this sheet is enclosed.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO

SIGNATURE

NIXON PEABODY LLP
8180 Greensboro Drive
Suite 800
McLean, Virginia 22102

Eric J. Robinson
NAME

38,285
REGISTRATION NUMBER

METHOD FOR MANUFACTURING AN OPTICAL FIBER PREFORM

TECHNICAL FIELD

5   The present invention relates to a method for manufacturing an optical fiber preform, in which a glass rod for the core, or a glass rod for the core and the cladding, is inserted into a glass pipe for the cladding, the pressure inside the glass pipe is reduced while the glass rod and glass pipe are heated, and the glass pipe and the glass rod

10   are formed into a single unit and are elongated.

BACKGROUND ART

Three methods can be offered as the principle methods for manufacturing optical fiber preforms: OVD (Outside Vapor

15   Deposition), VAD (Vapor-phase Axial Deposition) and MCVD (Modified Chemical Vapor Deposition). From the standpoint of productivity, in VAD and MCVD methods the cladding, which comes to occupy a major portion of the optical fiber preform, is formed around the outer circumference of the glass rod by

20   a separate process after the glass rod for the core or for the core and the cladding has been manufactured.

More specifically, a so-called external adhering method is known as a method for forming the cladding, wherein, for example, fine glass particles called "soot" are deposited on

25   the glass rod and are heated to make transparent glass.

In contrast, JP S56-45867B, for example, discloses a so-called rod-in-tube method, wherein a glass rod for the core or for the core and the cladding is inserted into a glass pipe for the cladding, which has been manufactured

30   beforehand in a separate process, and the glass pipe and glass rod are formed into a single unit. More specifically,

for this rod-in-tube method, a method is known wherein the glass pipe and glass rod are heated by a burner flame so as to press the glass pipe onto the glass rod by the gas of this burner flame, thereby forming the glass pipe and glass rod

5   into a single unit. Moreover, in a different known rod-in-tube method, the pressure within the glass pipe is reduced while the glass pipe and the glass rod are heated by a heating furnace (heater), for example, so as to form the glass pipe and the glass rod into a single unit by the

10   pressure difference between the inside and the outside of the glass pipe.

Optical fiber preforms manufactured by the above manufacturing methods are made into optical fiber by performing a fiber-drawing process, and JP S50-85345A, for

15   example, discloses a method for conducting a fiber-drawing process at the same time that the optical fiber preform is manufactured by a rod-in-tube method.

In recent years, from the standpoint of reducing production costs, for example, in order to meet demands for

20   optical fiber preform of an increased size, optical fiber preforms have been given a large diameter. When an optical fiber preform with a large diameter is drawn into a fiber as is, however, a long period of time is required before it can be stabilized into an optical fiber of a target diameter, and

25   a large amount of preform is consumed.

In light of the above, before an optical fiber preform with a large diameter is drawn into fiber, a diameter reducing process is normally performed to reduce its diameter to the optimal diameter for producing the greatest yield.

30   For example, JP H07-10580A discloses a method for manufacturing an optical fiber preform using the above-

mentioned rod-in-tube method and simultaneously reduceing the diameter of that optical fiber preform, so as to improve productivity.

However, when an optical fiber preform is manufactured by forming the glass pipe and a glass rod into a single unit, bubbles or the like may form between the glass pipe and the glass rod. These bubbles increase the transmittance loss and cause the difficulties of uniform connection of the optical fiber, and therefore bubbles must be reliably prevented during the manufacturing of optical fiber preforms. The following first and second problems are related to the prevention of these bubbles.

A first problem relates to the pressure inside of the glass pipe when the glass pipe and the glass rod are formed into a single unit.

That is, one reason why the above-mentioned bubbles occur is because of defects in the inner wall of the glass pipe, and also because of moisture and gas that adheres to the inner wall of the glass pipe. Therefore, to prevent bubbles due to defects, for example, in the inner wall of the glass pipe, the glass rod is normally inserted into the glass pipe after the inner wall of the glass pipe has been thoroughly cleaned and moisture, for example, has been completely removed. Furthermore, to prevent the remaining of gas that has adhered to the inner wall of the glass pipe, when the glass pipe and the glass rod are to be formed into a single unit, the pressure in the glass pipe is set to an extremely low pressure (pressure reduction level is raised), and then the glass pipe and the glass rod are formed into a single unit.

However, if the pressure reduction level within the

glass pipe is raised for the purpose of preventing bubbles, then the glass pipe attempts to suddenly reduce its diameter, so that the curvature in the reduced portions becomes large, and the amount of thickness aberration increases. This
5 results in the problem of core eccentricity becoming larger when the glass pipe and the glass rod have been formed into a single unit. Core eccentricity easily becomes particularly large when a large-scale glass pipe, for example a thick-walled glass pipe with a small inner to outer diameter ratio,
10 or a glass pipe with a large outer diameter, is used for the purpose of manufacturing a large optical fiber preform. In order to prevent core eccentricity, it is effective to form the glass pipe and the glass rod into a single unit in a state in which the level of pressure reduction within the
15 glass pipe has been lowered, but if the level of pressure reduction is lowered, there is the risk that bubbles will form within the optical fiber preform as mentioned above.

Thus, the first problem when forming the glass pipe and the glass rod into a single unit to manufacture an optical
20 fiber preform is the conflicting demands for the prevention of bubbles from forming due to defects in the inner wall of the glass pipe, and the prevention of core eccentricity. This first problem is extremely difficult to solve, particularly when manufacturing large-scale optical fiber
25 preforms.

Next, a second problem relates to the gap (clearance) between the glass pipe and the glass rod.

When forming the glass pipe and the glass rod into a single unit to manufacture the optical fiber preform, the
30 glass pipe and the glass rod can be easier formed into a single unit and the core eccentricity when forming the glass

5

pipe and the glass rod into a single unit is smaller if the clearance is small.

However, if the clearance is made small, the glass rod and the glass pipe rub against one another when the glass rod
5   is inserted into the glass pipe, and defects occur in the inner wall of the glass pipe and the outer wall of the glass rod due to this rubbing. This results in the risk that bubbles, for example, may form between the glass pipe and the glass rod. In particular, when a long optical fiber preform
10 is manufactured, a long glass rod is inserted into a long glass pipe, and therefore it becomes extremely difficult to keep the glass rod and the glass pipe from rubbing against one another.

In view of the above, it would seem that the clearance
15 between the glass pipe and the glass rod could be made larger when the glass pipe and the glass rod are formed into a single unit and elongated. Specifically, the following four methods are conceivable.

A first method, as shown in Fig. 11, increases the
20 clearance between the glass pipe and the glass rod by using a glass pipe which has the same outer diameter as a conventional glass pipe, and only the inner diameter is larger. The dash-dotted line in Fig. 11 shows the inner diameter of a conventional glass pipe. With this first
25 method, there is the problem that although rubbing between the glass pipe and the glass rod is avoided, the cross section area of the glass pipe becomes small, and the area of the cladding portion is insufficient when the glass pipe and the glass rod are formed into a single unit. That is, the
30 core/cladding ratio (value of the cladding diameter divided by the core diameter, hereinafter abbreviated as C/C) of the

optical fiber preform must be a predetermined value, and the cross section area of the glass pipe must correspond to the cross section area of the core in the glass rod. With the first method, to set the C/C of the completed optical fiber

5 preform to a predetermined value, the glass pipe having an insufficient amount of cross section area must be provided with additional coats, and therefore it is necessary to carry out glass pipe coating two or more times. For this reason, there is the problem that together with an increase in

10 production costs, the increase in the number of coats raises the risk that bubbles will form in the interface of the additionally coated glass pipe, and therefore the preform will become defective.

In a second method, as shown in Fig. 12, the clearance

15 between the glass pipe and the glass rod is increased by using a glass pipe which has the same cross section area as a conventional glass pipe, but has a larger inner and outer diameter. With this second method, although rubbing between the glass pipe and the glass rod is avoided, the diameter of

20 the glass pipe must be significantly reduced until the inner diameter of the glass pipe becomes the outer diameter of the glass rod. For this reason, there is the risk that the glass pipe will not uniformly reduce its diameter, thus increasing the amount of core eccentricity in the optical fiber preform.

25 Moreover, because the cross section area of the glass pipe is the same as that of a conventional glass pipe, the outer diameter increases in proportion to the amount that the inner diameter is increased. In particular, when manufacturing optical fibers in which the cladding is large with respect to

30 the core, such as single mode optical fibers, it is necessary to use a glass pipe that has a large cross section area, and

thus the glass pipe comes to have an even larger outer diameter. In this case, in addition to the occurrence of the above-mentioned problems, there is the problem that large glass pipes are difficult to obtain and expensive, and

5   because the glass pipe has a large outer diameter, there is also the problem that manufacturing equipment such as the heating furnace must also be large, thereby resulting in increased equipment costs and operating costs.

In a third method, as shown in Fig. 13, the clearance

10 between the glass pipe and the glass rod is increased by elongating the glass rod to reduce its diameter, rather than increase the inner diameter of the glass pipe. The dash-dotted line in Fig. 13 indicates the outer diameter of a conventional glass rod. Also in this third method, although

15 rubbing between the glass pipe and the glass rod is avoided, the cross section area of the glass pipe becomes too large with respect to the cross section area of the core in the glass rod, and it becomes difficult to set the C/C of the completed optical fiber preform to a predetermined value.

20 That is, the cross section area of the core in the glass rod becomes smaller by elongating the glass rod, and thus the required cross section area of the glass pipe also becomes smaller. However, because the glass pipe has the same cross section area as a conventional glass pipe, if the glass pipe

25 and the glass rod are formed into a single unit and are elongated, the C/C of the completed optical fiber preform significantly exceeds the predetermined value. In order to set the C/C of this optical fiber preform to the predetermined value it would seem that unnecessary portions

30 on the glass pipe could be removed by flame polishing, for example, but if portions of the glass pipe are removed, the

optical fiber preform is reduced in size. Moreover, by requiring a heretofore unnecessary flame polishing step, the number of production steps is increased, thereby leading to an increase in production costs. Note that if a glass pipe
5   is used that has a cross section area corresponding to the diameter of the elongated glass rod, an optical fiber preform with the predetermined C/C can be obtained, but there is the problem that in this case the optical fiber preform is reduced in size and productivity is lowered.

10   A fourth method is conceivable particularly for the manufacturing of optical fiber preforms for a single mode optical fiber, and as shown in Fig. 14, this method secures clearance between the glass pipe and the glass rod not by elongating the glass rod, but rather by removing the cladding
15   portion of the glass rod to reduce its outer diameter while maintaining the diameter of the core. Also with this fourth method, rubbing between the glass pipe and the glass rod can be avoided, but the losses in the optical fiber that is drawn out from the completed optical fiber perform are high. That
20   is, there may be residual OH groups, which absorb the signal light that propagates through the optical fiber core, at the interface between the glass rod and the glass pipe in the optical fiber preform. In consideration of the above, normally the outer diameter of the glass rod is made large so
25   as to provide distance between the interface of the glass rod and the glass pipe, and the core, and thus, even if there are residual OH groups at the interface of the glass rod and the glass pipe, the optical fiber is not easily affected by the effects of signal light absorption by these OH groups. For
30   example, when manufacturing an optical fiber preform for a 1.3 μm band single mode optical fiber, the outer diameter of

fiber preform wherein both the formation of bubbles and core eccentricity could be reliably prevented, thus conceiving of a first invention.

That is, it was found that when the glass pipe and the glass rod are formed into a single unit and are elongated, it is particularly important that the pressure reduction level in the glass pipe is optimized to prevent both the formation of bubbles and core eccentricity. In light of this, the inventors repeatedly performed experiments with a focus on this pressure reduction level, and from those results found the pressure reduction level in the glass pipe at which core eccentricity does not occur and the formation of bubbles can be reliably prevented, or in other words, found the optimal pressure reduction level. Then, when the glass pipe and the glass rod were formed into a single unit and elongated using this optimal pressure reduction level, it was found that either the glass pipe or the glass rod, or both, were elongated before forming into a single unit, and then the glass rod and the glass pipe formed into a single unit. For example, when the pressure reduction level is too high, the glass pipe and the glass rod are elongated after they have formed into a single unit, in which case it becomes easy for core eccentricity to occur, as mentioned above. On the other hand, when the pressure reduction level is too low, the glass pipe and the glass rod are not formed into a single unit, and after they have both been sufficiently elongated they tend to form into a single unit, but in this case they are not completely formed into a single unit. In contrast, at an optimal pressure reduction level, the glass pipe and the glass rod are formed into a single unit after the glass pipe or the glass rod, or both, have been elongated. Moreover, it

was confirmed that both the formation of bubbles and core eccentricity are reliably prevented when the glass pipe and the glass rod are formed into a single unit after the glass pipe or the glass rod, or both, have been elongated. Furthermore, it was confirmed that both the formation of bubbles and core eccentricity are reliably prevented even when a glass pipe with a large diameter or a glass pipe with a thick wall is used, thus conceiving of a first invention.

More specifically, the first invention is for a method for manufacturing an optical fiber preform, wherein a glass rod for the core or a glass rod for the core and the cladding is inserted into a glass pipe for the cladding, the pressure in the glass pipe is reduced while the glass pipe and the glass rod are heated, and the glass pipe and the glass rod are formed into a single unit and are elongated.

Then, the glass pipe and the glass rod are formed into a single unit after the glass pipe or the glass rod, or both, has been elongated, after which the glass pipe and glass rod that have been formed into a single unit are elongated until the outer diameter of the glass pipe becomes a predetermined diameter.

Here, the value of the optimal pressure reduction level depends on the temperature conditions of the heating furnace that heats the glass pipe and the glass rod, and the shape of the glass pipe and the glass rod, for example the size of the gap between the glass pipe and the glass rod. For that reason, it is difficult to regulate all optimal manufacturing conditions with the pressure reduction level. In light of this problem, the inventors found that optical manufacturing conditions can be set if the distance with respect to the longitudinal direction of the glass pipe and the glass rod is

utilized, instead of regulating the above-mentioned pressure reduction level, thus conceiving of a second invention.

More specifically, the second invention is characterized in that when the length from the position at

5   which the glass pipe or the glass rod, or both, begin to be elongated to the position at which the glass pipe and the glass rod are formed into a single unit is $L1$, and the length from the position at which the glass pipe and the glass rod are formed into a single unit to the position at which the

10 glass pipe and the glass rod are elongated so that the outer diameter of the glass pipe becomes a predetermined diameter is $L2$, then the glass pipe and the glass rod are formed into a single unit and are elongated so as to satisfy the equation $0.1 \leqq L1/(L1+L2) \leqq 0.8$.

15 Furthermore, the inventors found that the amount of core eccentricity also depends on the size of the clearance. For example, when there is a large clearance, the curvature of the glass pipe increases when the glass pipe diameter is reduced by shrinking, and thus core eccentricity easily

20 occurs. Then, the optimal manufacturing conditions obtained by regulating the clearance were found, and thus a third invention was achieved.

More specifically, the third invention is characterized in that when the outer diameter of the glass pipe is $D0$ and

25 the inner diameter of the glass pipe is $d0$, the outer diameter of the glass pipe is $D1$ and the inner diameter of the glass pipe is $d1$ at the position where the glass pipe and the glass rod become a single unit, then the glass pipe and the glass rod are formed into a single unit and elongated so

30 as to satisfy the equation $(d0/D0)/(d1/D1) \leqq 2$.

For example, when the value of $(d0/D0)/(d1/D1)$ is large,

that is, when there is a large clearance, there is the risk that the curvature of the reduced glass pipe diameter will increase and cause core eccentricity, however, core eccentricity can be reliably prevented by setting the value

5 of $(d0/D0)/(d1/D1)$ to 2 or less, as in the above-mentioned third invention.

The method for manufacturing an optical fiber preform according to the first through third inventions is also suited for the manufacturing of large-scale optical fiber

10 preform, so that it becomes possible to manufacture an optical fiber preform while preventing the formation of bubbles and core eccentricity even when, for example, a thick-walled glass pipe with an inner to outer diameter ratio of 0.5 or less is used, or a glass pipe with a large outer

15 diameter of 48 mm or more is used.

On the other hand, to solve the above-mentioned second problem, the inventors secured the clearance between the glass pipe and the glass rod not by making the inner diameter of the glass pipe large, but rather by focusing on and

20 improving the diameter reduction by elongating the glass rod. That is, when the glass rod is elongated as in the aforementioned third method, problems occur due to the reduction in diameter of the core in the glass rod. However, if the feed rate of the elongated glass rod when it is feed

25 into the heating furnace is faster than the feed rate of the glass pipe, then the cross section area of the glass rod at the position at which the glass pipe and the glass rod are formed into a single unit becomes larger than when the feed rate of the glass rod and the feed rate of the glass pipe are

30 the same. Thus, in light of this point a fourth invention was achieved.

More specifically, the fourth invention is for a method
for manufacturing an optical fiber preform, wherein a glass
rod for a core or a glass rod for the core and a cladding is
inserted into a glass pipe for the cladding, the pressure in
5   the glass pipe is reduced while the glass pipe and the glass
rod are heated by a heating furnace, and the glass pipe and
the glass rod are both formed into a single unit and
elongated.

Then, the feed rate at which the glass rod is fed into
10   the heating furnace is adjusted such that it is faster than
the feed rate of the glass pipe and not more than twice the
feed rate of the glass pipe.

Here, the glass rod can have been reduced in diameter
by elongating, for example, that is to say, it can be a glass
15   rod that has been reduced in diameter without its C/C being
altered.

According to the fourth invention, by making the feed
rate of the glass rod larger than the feed rate of the glass
pipe, the cross section area of the glass rod when the glass
20   rod and the glass pipe are formed into a single unit is
larger than when the feed rate of the glass rod and the feed
rate of the glass pipe are the same. That is, when the feed
rate of the glass rod and the feed rate of the glass pipe are
the same, the ratio of the cross section area of the glass
25   rod to the cross section area of the glass pipe is always
kept constant, but by making the feed rate of the glass rod
faster than the feed rate of the glass pipe, the ratio of the
cross section area of the glass rod to the cross section area
of the glass pipe changes, and thus the glass pipe and the
30   glass rod are formed into a single unit in a state wherein
the cross section area of the glass rod has increased

relative to the cross section area of the glass pipe. Consequently, by increasing the ratio of the cross section area of the glass pipe to the cross section area of the glass rod, the effects of core diameter reduction due to the elongating of the glass rod are canceled, and the C/C of the optical fiber preform obtained by forming the glass pipe and the glass rod into a single unit becomes the target C/C.

The feed rate of the glass rod is set to not more than twice the feed rate of the glass pipe for the following reason. For example, if the feed rate of the glass rod is too much faster than the feed rate of the glass pipe, then the glass rod becomes several times the length of the glass pipe. Also, when the glass pipe and the long glass rod that is inserted into the glass pipe are fed into the heating furnace, it is necessary that the equipment for drawing the optical fiber preform is of an extremely large size. Because of the resulting difficulty in achieving all of the above, the feed rate of the glass rod should be not more than twice the feed rate of the glass pipe.

The method for manufacturing an optical fiber preform according to the fourth invention is particularly effective when, as in a fifth invention, an elongated glass rod that whose diameter is small in comparison to the cross section area of the glass pipe is used so that the gap between the glass pipe and the glass rod becomes large, and the feed rate of the glass rod is adjusted so that when the glass pipe and the glass rod become a single unit, the set core/cladding ratio is achieved.

In this case, the clearance becomes relatively large by setting the glass rod to a small diameter, even if the inner diameter of the glass pipe is not large. For this reason,

rubbing between the glass pipe and the glass rod is avoided, and the formation of bubbles is prevented. An optical fiber preform with the target C/C can be manufactured as mentioned above by increasing the feed rate of the glass rod, even if

5　the glass rod has a small diameter. Furthermore, because the inner diameter of the glass pipe is not large, the diameter of the glass pipe is uniformly reduced and thus core eccentricity is avoided. Moreover, a large heating furnace is unnecessary, and the cross section area of the glass pipe

10　does not have to be small to correspond to the reduced diameter of the glass rod, and thus large optical fiber preforms can be manufactured.

　　If, as in the fourth and fifth inventions, the ratio (V_R/V_P) of the feed rate of the glass pipe V_P to the feed rate

15　of the glass rod V_R is set to $1 < (V_R/V_P) \leqq 2$, then, for example, when a large-sized and long optical fiber preform with a clearance set to about 5 to 15 mm is manufactured using a glass rod with an outer diameter of about 25 to 45 mm, and a glass pipe with an inner diameter of about 50 to 55 mm,

20　problems such as the formation of bubbles and core eccentricity can be reliably avoided.

　　However, what becomes a particular problem in the manufacturing of a large-sized and long optical fiber preform is when the core diameter, the refractive index difference

25　between the core and the cladding, or the C/C change in the longitudinal direction of the glass rod that is used in the manufacturing of this optical fiber preform and which has been manufactured by VAD, for example. If such a glass rod in which the structure has changed in the longitudinal

30　direction is formed into a single unit with the glass pipe at the same feed rate as the glass pipe to make optical fiber

preform, then the C/C of this optical fiber preform reflects the structural changes in the longitudinal direction of the glass rod and changes in the longitudinal direction.

For this reason, normally the glass rod is partitioned in longitudinal direction into a plurality of glass rods, a target C/C suited to the structure of each of the partitioned glass rods is set and the manufacturing process is adjusted at each of the partitioned glass rods, so that the cut-off wavelength in the optical fiber has the desired value. For example, large sections of the core diameter in the glass rods are cut away and the cut glass rods are elongated, and the portions in the glass rods in which there is a large difference in refractive index between the core and the cladding are cut away, and then the glass rods are set to a target C/C that is higher than normal and the glass rods and the glass pipe are formed into a single unit.

However, partitioning the glass rod into a plurality of glass rods and individually adjusting the manufacturing process for each of the partitioned glass rods causes problems such as a drop in yield and the complication of managing the manufacturing process.

A sixth invention solves these problems. More specifically, it is characterized by adjusting the feed rate of the glass rod so as to form the glass pipe and the glass rod into a single unit at a desired core/cladding ratio in the longitudinal direction.

Here, what is meant by "form the glass pipe and the glass rod into a single unit at a desired core/cladding ratio in the longitudinal direction" is that even if irregularities in the core diameter, the refractive index difference between the core and the cladding, or the C/C occur in longitudinal

direction in the glass rod, these irregularities are canceled so that the glass pipe and the glass rod can be formed into a single unit to make an optical fiber preform with the target C/C.

5   According to this sixth invention, an optical fiber preform with a desired C/C can be obtained even if in the glass rod the core diameter, the refractive index difference between the core and the cladding, or the C/C change in the longitudinal direction. For example, if the glass rod has a

10   refractive index difference between the core and the cladding that is substantially constant in the longitudinal direction but the C/C increases from the end at which glass rod and glass pipe integration begins toward the end at which integration finishes, then an optical fiber preform with a

15   desired C/C in the longitudinal direction is manufactured if the feed rate of this glass rod is gradually increased while it is formed into a single unit with the glass pipe. Or, if the glass rod has a C/C that is substantially constant in the longitudinal direction but the refractive index difference

20   between the core and the cladding increases from the end at which glass rod and glass pipe integration begins toward the end at which integration finishes, then an optical fiber preform with a desired C/C in the longitudinal direction is manufactured if the feed rate of this glass rod is gradually

25   reduced while it is formed into a single unit with the glass pipe. Or, if in the glass rod, both the refractive index difference between the core and the cladding and the C/C increase from the end at which glass rod and glass pipe integration begins toward the end at which integration

30   finishes, then an optical fiber preform with a desired C/C in the longitudinal direction is manufactured if the target C/C

is set at tiny increments in the longitudinal direction of this glass rod, and the feed rate of the glass rod is increased and decreased based on the set target C/C ratios as the glass rod and the glass pipe are formed into a single

5   unit.

Optical fiber drawn from large optical fiber preforms processed in this way has a stable cut-off wavelength in the longitudinal direction. Furthermore, the manufacturing of optical fiber at an improved process yield and low cost is

10   achieved.

The feed rate of the glass rod can be controlled by a executing a control program, for example, in which the amount of change in the core diameter, refractive index difference between the core and the cladding, or the C/C, in the

15   longitudinal direction of the glass rod is measured or estimated before the glass rod and the glass pipe become a single unit, and then the program is configured based on this amount of change. Furthermore, when the refractive index difference between the core and the cladding in the glass rod

20   is substantially constant in the longitudinal direction, a feedback control can be performed in which the feed rate of the glass rod is controlled according to values obtained by measuring the core diameter while the glass rod and the glass pipe are being formed into a single unit.

25   It should be noted that the same operation and effects as mentioned above can also be obtained by adjusting the feed rate of the glass pipe.

The glass rod and the glass pipe are normally formed into a single unit once any bend deformations in their shape

30   have been corrected, but particularly in the case of manufacturing large-sized and long optical fiber preforms, it

becomes difficult to correct bends in the glass rod and the glass pipe, because the glass rod and the glass pipe are large. On the other hand, if they are formed into a single unit without correcting these bends, then there is the risk

5   that the amount of core eccentricity in the optical fiber preform will increase.

The seventh invention solves this problem. More specifically, it is characterized in that the glass pipe and the glass rod are formed into a single unit while the glass

10   pipe or the glass rod, or both, are rotated around the longitudinal axis of the glass pipe or glass rod.

When, as in the seventh invention, the glass rod or the glass pipe, or both, are rotated around the longitudinal center axis while they are being formed into a single unit,

15   then the amount of core eccentricity decreases because the axial symmetry with respect to the longitudinal center axis in the optical fiber preform is improved. From the fact that polarization diffraction properties improve if the amount of core eccentricity is decreased, with the method for

20   manufacturing optical fiber according to the seventh invention, it is possible to obtain a more precise optical fiber, and a large optical fiber preform can be manufactured.

BRIEF DESCRIPTION OF THE DRAWINGS

25   Fig. 1 is a perspective view illustrating how an optical fiber preform is manufactured.

Fig. 2 is a perspective view showing how the glass pipe and the glass rod being are formed into a single unit by the method for manufacturing an optical fiber preform according

30   to the first embodiment.

Fig. 3 is a diagram that corresponds to Fig. 2 and

shows how the glass pipe and the glass rod are formed into a single unit by a conventional method for manufacturing an optical fiber preform.

Fig. **4** shows the experimental results of an evaluation of the bubbles inside an optical fiber preform, and the amount of measured core eccentricity in the optical fiber drawn out from an optical fiber preform, when manufacturing the optical fiber preforms at various $L1/(L1+L2)$ values.

Fig. **5** shows the experimental results of an evaluation of the bubbles inside an optical fiber preform, and the amount of measured core eccentricity in the optical fiber drawn out from an optical fiber preform, when manufacturing optical fiber preforms at various $(d0/D0)/(d1/D1)$ values.

Fig. **6** is a diagram that corresponds to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when there is a small clearance.

Fig. **7** is a diagram that corresponds to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when there is a large clearance.

Fig. **8** is a diagram showing the amount of core eccentricity and the number of formed bubbles as a function of $L1/(L1+L2)$, as obtained by experiment.

Fig. **9** is a diagram showing the amount of core eccentricity as a function of $(d0/D0)/(d1/D1)$, as obtained by experiment.

Fig. **10** is a diagram that corresponds to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit by the method for manufacturing an optical fiber preform according to the second embodiment.

Fig. **11** is a diagram corresponding to Fig. **2** and shows how the glass pipe and the glass rod how formed into a single

unit when a glass pipe having a large inner diameter is used.

Fig. **12** is a diagram corresponding to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when a glass pipe having a large inner and outer diameter is used.

Fig. **13** is a diagram corresponding to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when a glass rod having an outer diameter that has been reduced by elongating is used.

Fig. **14** is a diagram corresponding to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when the glass rod that is used has an outer diameter that has been reduced by removing the cladding portion.

Fig. **15** is a diagram corresponding to Fig. **2** and shows how the glass pipe and the glass rod are formed into a single unit when there is a small clearance.

Fig. **16** shows the experimental results of an evaluation of the bubbles inside an optical fiber preform, and the amount of measured core eccentricity in the optical fiber drawn out from an optical fiber preform, in a case wherein optical fiber preforms were manufactured at various clearances and glass rod feed rates.

BEST MODE FOR CARRYING OUT THE INVENTION

First Embodiment

The first embodiment corresponds to the first through third inventions.

Fig. **1** illustrates the state during the manufacturing of an optical fiber preform according to the first embodiment. Numeral **1** denotes a glass pipe for the cladding, numeral **2** denotes a glass rod for the core or for the core and the

cladding, and numeral **3** denotes a heater for heating both the glass pipe **1** and the glass rod **2**. For the glass pipe **1**, it is possible to use a glass pipe that has been manufactured by OVD, for example. Furthermore, the glass rod **2** can be a
5 glass rod made by sintering a deposit of fine glass particles that have been deposited by the VAD method, or a glass rod made by forming and solidifying core glass on the inner wall of a cladding pipe by MCVD. Furthermore, for the furnace provided with the heater **3**, more specifically a carbon
10 resistance furnace or a high-frequency induction furnace can be used.

The manufacturing procedure of the optical fiber preform is explained next. First, in a state wherein the upper ends of the glass pipe **1** and the glass rod **2** are held
15 by a holding device, which has been omitted from the drawings, the glass rod **2** is inserted into the glass pipe **1** such that it is coaxial with the glass pipe **1**. Then, while the pressure inside the glass pipe **1** is reduced by a pressure reducing device, which has been omitted from the drawings,
20 the glass pipe **1** and the glass rod **2** are moved downward by the holding device such that they are positioned within the heater **3** (see arrows in Fig. 1).

The glass pipe **1** and the glass rod **2** are heated by the heater **3**, and once the glass pipe **1** has melted, the
25 difference in pressure inside and outside the glass pipe **1** causes the glass pipe **1** and the glass rod **2** to become a single unit. Formed into a single unit, the optical fiber preform **4** is drawn by a drawing device (omitted from the drawings) provided below the heater, and is elongated
30 downwards (see arrows in Fig. 1), and thus the glass pipe **1** and the glass rod **2** are formed into a single unit at the same

time that the optical fiber preform **4** is elongated.

In the first embodiment, as shown in Fig. 2, by adjusting the level of pressure reduction within the glass pipe **1**, the glass rod **2** is pre-elongated before the glass
5   pipe **1** and the glass rod **2** are formed into a single unit, and then the glass pipe **1** and the glass rod **2** are formed into a single unit. This means that the glass rod **2** begins to elongate at a position that is above the position at which the glass pipe **1** and the glass rod **2** become a single unit
10 (see *L1* in Fig. 2). Note that *L2* in the drawing shows the length between the position at which the glass pipe **1** and the glass rod **2** become a single unit, and the position at which the outer diameter of the glass pipe **1** becomes a predetermined diameter D2 due to the elongating of the glass
15 pipe **1** and the glass rod **2** which have been formed into one unit.

On the other hand, Fig. 3 shows how the glass pipe **1** and the glass rod **2** are formed into one unit in accordance with a conventional optical fiber manufacturing method. In
20 this case, the glass pipe **1** and the glass rod **2** become a single unit with neither of them being elongated, and the optical fiber preform **4** is elongated only after they have been formed into one unit, and therefore there is no *L1*.

The following is a description of an experiment that
25 was conducted with method for manufacturing an optical fiber preform according to the first embodiment.

Fig. **4** shows the experimental results of an evaluation regarding bubbles formed in the optical fiber preform **4**, and the amount of core eccentricity in the optical fiber drawn
30 out from the optical fiber preform **4**, when the optical fiber preform **4** was manufactured using various glass pipes **1** and

glass rods **2**, and the value of $L1/(L1+L2)$ as the parameter was changed by altering the pressure reduction level within the glass pipe **1**. Fig. **5** shows the experimental results of an evaluation regarding bubbles formed in the optical fiber preform **4**, and the amount of core eccentricity in the optical fiber, when the optical fiber preform **4** was manufactured using various glass pipes **1** and glass rods **2**, when the gap (clearance: $(d0/D0)$ / $(d1/D1)$) between the glass pipe **1** and the glass rod **2** is small (see Fig. **6**), and when the clearance is large (see Fig. **7**).

Here, $D0$ and $d0$ are the outer diameter and inner diameter of the glass pipe **1** before elongating, $D1$ and $d1$ are the outer diameter and inner diameter of the glass pipe **1** at the position of integration, and $D2$ and $d2$ are the outer diameter (optical fiber preform diameter) and inner diameter of the glass pipe **1** when the elongating operation is finished. Furthermore, d is the outer diameter of the glass rod **2** before elongating.

Working Examples 1 to 8 in Fig. **4** are examples in which the optical fiber preform **4** was manufactured by adjusting the level of pressure reduction within the glass pipe **1** so as to pre-elongate the glass rod **2** before the glass pipe **1** and the glass rod **2** are formed into a single unit (see Fig. **2**), and of Working Examples 1 to 8, in Working Examples 1 to 5, the glass pipe **1** has a relatively small outer diameter $D0$, whereas in Working Examples 6 to 8, the glass pipe **1** has a relatively large outer diameter $D0$.

Furthermore, Working Examples 9 to 14 in Fig. **5** are examples in which the optical fiber preform **4** was manufactured by adjusting the pressure reduction levels within the glass pipe **1** so as to pre-elongate the glass rod **2**

before the glass pipe **1** and the glass rod **2** are formed into a single unit, and of Working Examples 9 to 14, in Working Examples 9 to 12, the outer diameter DO of the glass pipe **1** is relatively small, whereas in Working Examples 13 and 14,

5 the outer diameter DO of the glass pipe **1** is relatively large.

On the other hand, in Conventional Examples 1 and 2, neither the glass pipe **1** nor the glass rod **2** are pre-elongated before they are formed into a single unit, and the optical fiber preform **4** is manufactured by elongating the

10 glass pipe **1** and the glass rod **2** only after they have become a single unit (see Fig. 3). In Conventional Example 1, the outer diameter DO of the glass pipe **1** is relatively small, whereas in Conventional Example 2, the outer diameter DO of the glass pipe **1** is relatively large.

15 Moreover, in Comparative Example 1 in Fig. **4**, the level of pressure reduction in the glass pipe **1** is small, and the glass pipe **1** and the glass rod **2** were not completely formed into a single unit ($L2=0$).

Fig. **8** is a diagram based on Fig. **4** and Fig. **5**, in

20 which the value of $L1/(L1+L2)$ is plotted along the horizontal axis, and the number of bubbles formed in the optical fiber preform (black squares) and the amount of core eccentricity of the optical fiber (white triangles) are plotted along the vertical axis. From Fig. **8**, it can be seen that if the value

25 of $L1/(L1+L2)$ is at least 0.1 and not more than 0.8, then the formation of bubbles and core eccentricity are both prevented. This trend is the same even when the outer diameter DO of the glass pipe **1** is large, as in Working Examples 6 and 7, for example, and it was found that the formation of bubbles and

30 core eccentricity were reliably prevented even when the glass pipe **1** had a large diameter (large DO) or was thick walled

(small $d0/D0$).

From the above results, it was possible to confirm that the optical fiber preform 4 can be manufactured under the prevention of bubbles and eccentricity by elongating the

5   glass pipe 1 and the glass rod 2 and forming them into a single unit such that $0.1 \leqq L1/(L1+L2) \leqq 0.8$.

Fig. 9 is also a diagram based on Fig. 4 and Fig. 5, in which the value of $(d0/D0)/(d1/D1)$ is plotted on the horizontal axis, and the amount of core eccentricity is

10   plotted on the vertical axis. From Fig. 9, it was found that core eccentricity is prevented if the value of $(d0/D0)/(d1/D1)$ is not larger than 2, that is, when there is a relatively small clearance.

From the above results, it was possible to confirm that

15   the optical fiber preform 4 can be manufactured under prevention of core eccentricity by forming the glass pipe 1 and the glass rod 2 into one unit and elongating them such that $(d0/D0)/(d1/D1) \leqq 2$.

It should be noted that with the method for

20   manufacturing an optical fiber preform according to the first embodiment, the same effects can also be obtained if the glass pipe 1 and the glass rod 2 are elongated upward, opposite from the illustration in Fig. 1.

25   Second Embodiment

The second embodiment corresponds to the fourth through seventh invention. The basic configuration of the method for manufacturing an optical fiber preform according to the second embodiment is substantially the same as that of the

30   first embodiment (see Fig. 1), and thus only different aspects will be explained.

The grasping device, which has been omitted from the drawings, grasps the upper ends of the glass pipe **1** and the glass pipe **2** and is configured such that it can move the glass pipe **1** and the glass rod **2** in a downward direction, but
5   the moving directions can be set to feed rates for the glass pipe **1** and the glass rod **2** (feeding speed toward the heater **3**) that differ from one another.

Furthermore, the holding device is configured such that it is able to rotate the glass rod **2** around the axis X in the
10   longitudinal direction of the glass rod **2**, and when necessary, to form the glass pipe **1** and the glass rod **2** into a single unit while rotating the glass rod **2**.

The following describes the manufacturing of the above optical fiber preform **4**. The glass rod **2** that is used in the
15   second embodiment has been elongated to relatively small diameter (see d of Fig. **10**), and on the other hand, the glass pipe **1** is a conventional glass pipe. Thus, the gap (clearance) between the glass rod **2** and the glass pipe **1** is relatively large.

20   Then, in a state wherein the glass rod **2** has been inserted into the glass pipe **1**, the glass pipe **1** and the glass rod **2** are moved downwards while the pressure inside the glass pipe **1** is reduced by the pressure reducing device, and at this time the feed rate V_R of the glass rod **2** is set so
25   that it is faster than the feed rate V_p of the glass pipe **1**. Thus, the outer diameter of the glass rod **2** at the position where the glass rod **2** is formed into a single unit with the glass pipe **1** becomes the outer diameter $d1$ of the glass rod **2** that is necessary to achieve the set C/C for the optical
30   fiber preform **4**. As a result, the target C/C is attained for the integrally formed optical fiber preform **4**.

When for example the C/C of the glass rod **2** changes along the longitudinal direction of the glass rod **2**, then the feed rate V_R of the glass rod **2** is adjusted by a pre-set control program so that the C/C of the optical fiber preform

5   **4** becomes the predetermined C/C.

Thus, if the clearance is made relatively large by setting the outer diameter of the glass rod **2** to a small diameter, rubbing between the glass pipe **1** and the glass rod **2** can be avoided to prevent the formation of bubbles.

10   Moreover, by increasing the feed rate V_R of the glass rod **2**, the amount of the glass rod **2** that is fed per unit of time does not drop, even if the glass rod **2** has a small outer diameter. Therefore, even if the glass pipe **1** does not have a small cross section area, an optical fiber preform **4** with a

15   predetermined C/C can be manufactured, and a large optical fiber preform **4** can be manufactured. A glass pipe of the same size as a conventional glass pipe can be used for the glass pipe **1**, and thus there are no cost increases related for example to changing the size of the glass pipe **1**, and

20   moreover, the heating furnace does not have to be changed to a large heating furnace. Furthermore, because the glass pipe **1** does not have large inner or outer diameters, the glass pipe **1** uniformly reduces its diameter when the glass pipe **1** and the glass rod **2** become a single unit. Thus, eccentricity

25   of the core can be avoided.

Furthermore, adjusting the feed rate V_R of the glass rod by increasing or decreasing it, an optical fiber preform having a desired C/C can be manufactured even if the core diameter, the C/C, or the refractive index difference between

30   the core and the cladding in the glass rod **2** change in the longitudinal direction.

Furthermore, when necessary, the glass rod **2** can be formed into a single unit with the glass pipe **1** while it is rotated around its longitudinal central axis X to improve axial symmetry in the optical fiber **4** with respect to the longitudinal central axis X, and thus the amount of core eccentricity of the optical fiber preform **4** can be reduced.

It should be noted that it is also possible to perform a feedback control on the feed rate V_R of the glass rod **2** so as to control the feed rate V_R based on a measurement of the core diameter of the optical fiber **4** made while the glass pipe **1** and the glass rod **2** are formed into a single unit, for example.

It is also possible to adjust the feed rate of the glass pipe **1** instead of adjusting the feed rate V_R of the glass rod **2**. Also in this case, the same results and effects as above can be achieved.

Furthermore, the glass pipe **1** can be rotated around the longitudinal central axis X instead of rotating the glass pipe **2** around its longitudinal central axis X. This, too, improves the axial symmetry with respect to the longitudinal central axis X of the optical fiber preform **4**, and decreases the amount of core eccentricity of the optical fiber preform **4**. It is also possible to rotate both the glass pipe **1** and the glass rod **2**.

With the method for manufacturing an optical fiber preform according to this second embodiment, the same effects can be obtained even if the glass pipe **1** and the glass rod **2** are elongated upwards.

The following is a description of an experiment performed using the method for manufacturing an optical fiber preform according to the second embodiment.

Fig. **16** illustrates the results of an experiment performed to evaluate the formation of bubbles in the optical fiber preform, and the amount of core eccentricity measured after the optical fiber preform is drawn into optical fiber,

5   when the optical fiber preform is manufactured using a variety of glass pipes **1** and glass rods **2**, and changing the size of the clearance and the feed rate V_R of the glass rod **2** as parameters.

Here, d is the diameter of the glass rod **2** before it is

10 elongated, and $d1$ and $d1'$ are the outer diameter of the glass rod **2** (inner diameter of the glass pipe **1**) at the spot where the glass pipe **1** and the glass rod **2** are formed into a single unit. Further, V_R is the feed rate of the glass rod **2**, and V_P is the feed rate of the glass pipe **1**.

15 Furthermore, in the Working Example and Comparative Examples 1 and 2 of Fig. **16**, as shown in Fig. **10**, Fig. **13**, and Fig. **12**, there is a relatively large clearance, and therefore the optical fiber preform is manufactured without the glass pipe **1** and the glass rod **2** rubbing against each

20 other. In the Working Example, the optical fiber preform was manufactured by feeding the glass rod **2** at a faster feed rate ($V_R/V_P > 1$) than the glass pipe **1**.

On the other hand, in Comparative Example 3, as shown in Fig. **15**, there is a small clearance, and therefore the

25 glass pipe **1** and the glass rod **2** rub against each other during the manufacturing of the optical fiber preform.

From Fig. **16**, it was found that in Comparative Examples 1 and 2, in which there is a large clearance, the formation of bubbles resulting from rubbing between the glass pipe **1**

30 and the glass rod **2** is prevented, however, either the cut-off wavelength significantly differs from its target value

(Comparative Example 1), or there is an increase in the amount of core eccentricity (Comparative Example 2). Moreover, it was found that in the Comparative Example 3, in which there is a small clearance, bubbles form as a result of
5   rubbing between the glass pipe **1** and the glass rod **2**.

In contrast, in the Working Example, in which there was a large clearance and the feed rate V_R of the glass rod **2** was faster than the feed rate of the glass pipe **1**, both the formation of bubbles and core eccentricity were prevented,
10   and moreover, the cut-off wavelength of the obtained optical fiber was the value of the target cut-off wavelength.

From the above results, it was possible to confirm that with the method for manufacturing an optical fiber preform according to the second embodiment, it is possible to
15   manufacture a large optical fiber preform in which the formation of bubbles and core eccentricity are reliably prevented, and from which an optical fiber with the target cut-off wavelength can be obtained.

20

CLAIMS:

1.   A method for manufacturing an optical fiber preform, wherein a glass rod for a core or a glass rod for the core

5   and a cladding is inserted into a glass pipe for the cladding, pressure in the glass pipe is reduced while the glass pipe and the glass rod are heated, and the glass pipe and the glass rod are formed into a single unit and elongated, the method for manufacturing an optical fiber preform comprising:

10   forming the glass pipe and the glass rod into a single unit after the glass pipe or the glass rod, or both, has been elongated, and then elongating the glass pipe and glass rod that have been formed into a single unit, until the outer diameter of the glass pipe becomes a predetermined diameter.

15

2.   The method for manufacturing an optical fiber preform according to claim 1,

       wherein the length from a position at which the glass pipe or the glass rod, or both, begin to elongate to a

20 position at which the glass pipe and the glass rod become a single unit is $L1$, and

       the length from the position at which the glass pipe and the glass rod become a single unit to the position at which the glass pipe and the glass rod have elongated so that

25 the outer diameter of the glass pipe becomes a predetermined diameter is $L2$, then

       the glass pipe and the glass rod are formed into a single unit and elongated so as to satisfy the equation:

       $0.1 \leqq L1/(L1+L2) \leqq 0.8$.

30

3.   The method for manufacturing an optical fiber preform

according to claim 1 or claim 2,

wherein if the outer diameter of the glass pipe is *D0* and the inner diameter of the glass pipe is *d0*, and

if the outer diameter of the glass pipe is *D1* and the
5   inner diameter of the glass pipe is *d1* at the position at which the glass pipe and the glass rod become a single unit, then

the glass pipe and the glass rod are formed into a single unit and are elongated so as to satisfy the equation:
10   $(d0/D0)/(d1/D1) \leqq 2$.

4.   A method for manufacturing an optical fiber preform, wherein a glass rod for a core or a glass rod for the core and a cladding is inserted into a glass pipe for the cladding,
15   the pressure in the glass pipe is reduced while the glass pipe and the glass rod are heated by a heating furnace, and the glass pipe and the glass rod are formed into a single unit and are elongated, the method for manufacturing an optical fiber preform comprising:
20   adjusting the feed rate at which the glass rod is fed into the heating furnace such that it is faster than the feed rate of the glass pipe and not more than twice the feed rate of the glass pipe.

25   5.   The method for manufacturing an optical fiber preform according to claim 4,

wherein the elongated glass rod that is used has a smaller diameter in comparison to the cross section area of the glass pipe, so as to make the gap between the glass pipe
30   and the glass rod large, and

wherein the feed rate of the glass rod is adjusted such

that a set core/cladding ratio is achieved when the glass pipe and the glass rod are formed into a single unit.

6.   The method for manufacturing an optical fiber preform according to claim 4 or claim 5,

wherein the feed rate of the glass rod is adjusted such that the glass pipe and the glass rod are formed into a single unit at a desired core/cladding ratio in the longitudinal direction.

7.   The method for manufacturing an optical fiber preform according to claim 4 or claim 5,

wherein the glass pipe and the glass rod are formed into a single unit while the glass pipe or the glass rod, or both, are rotated around the longitudinal axis of the glass pipe or glass rod.

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FIG. 1
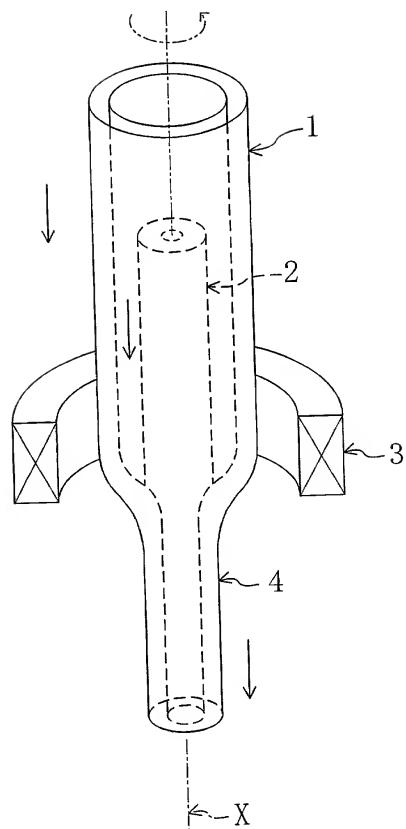
FIG. 2
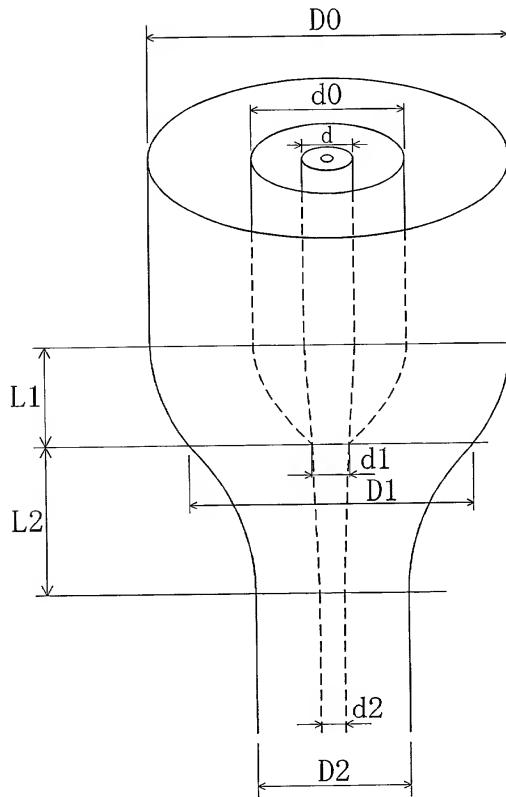
FIG. 3
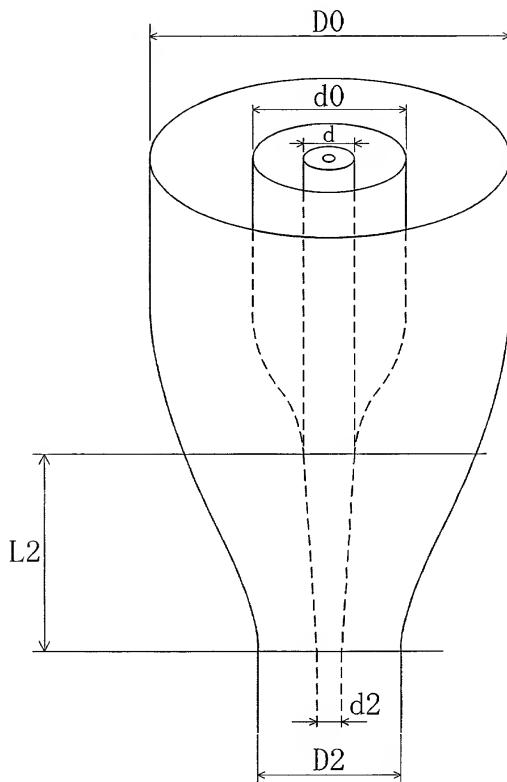
FIG. 4

	variable	Conv.Ex.1	Work.Ex.1	Work.Ex.2	Work.Ex.3	Work.Ex.4	Work.Ex.5	Comp.Ex.1	Conv.Ex.2	Work.Ex.6	Work.Ex.7	Work.Ex.8
pipe outer diameter	D0	67.0	48.0	67.0	67.0	67.0	67.0	67.0	170.0	170.0	166.0	170.0
pipe inner diameter	d0	23.0	24.0	23.0	23.0	23.0	23.0	23.0	55.0	55.0	66.0	55.0
rod diameter	d	19.0	13.0	19.0	19.0	19.0	19.0	19.0	45.0	45.0	41.6	45.0
pipe inner/outer diameter ratio	d0/D0	0.34	0.50	0.34	0.34	0.34	0.34	0.34	0.32	0.32	0.40	0.32
pipe outer diameter	D1	65.7	41.0	51.2	60.3	58.2	48.4	44.0	167.0	157.5	128.2	98.6
pipe inner diameter (=rod diameter)	d1	19.0	12.2	14.8	17.4	16.8	14.0	12.7	45.0	42.4	33.8	26.6
pipe inner/outer diameter ratio	d1/D1	0.29	0.30	0.29	0.29	0.29	0.29	0.29	0.27	0.27	0.26	0.27
pipe outer diameter	D2	44.0	30.0	44.0	44.0	44.0	44.0	44.0	60.0	60.0	60.0	60.0
pipe inner diameter (=rod diameter)	d2	12.7	9.0	12.7	12.7	12.7	12.7	12.7	16.2	16.2	15.8	16.2
pipe inner/outer diameter ratio	d2/D2	0.29	0.30	0.29	0.29	0.29	0.29	0.29	0.27	0.27	0.26	0.27
ratio of pipe inner/outer diameter ratios	$\frac{d0/D0}{d1/D1}$	1.19	1.68	1.19	1.19	1.19	1.19	1.19	1.20	1.20	1.51	1.20
initial stretching position to integrated position	L1	0	38	43	18	22	89	210	0	66	140	377
integrated position to final stretching position	L2	85	79	88	92	89	22	0	400	344	245	33
ratio of distance to integrated position over total distance	L1/(L1+L2)	0.00	0.32	0.33	0.16	0.20	0.80	1.00	0.00	0.17	0.36	0.92
pipe pressure reduction level (kPa)		100.0	13.3	13.3	53.3	26.6	6.7	3.3	100.0	40.0	13.3	3.3
heating temperature of stretching furnace (°C)		2250	2250	2250	2250	2250	2250	2250	2250	2250	2250	2250
feed rate of pipe into furnace (mm/min)		10.0	8.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
draw rate of stretched preform (mm/min)		22.3	16.9	22.3	22.3	22.3	22.3	22.3	77.5	77.5	69.3	77.5
bubbles in preform (per 100mm of preform)		0	0	0	0	0	2	124	0	1	1	12
mode field eccentricity amount of optical fiber (μm)		1.41	0.20	0.19	0.22	0.20	0.18	0.19	2.22	0.33	0.28	0.29

FIG. 5

	variable	Conv. Ex. 1	Work. Ex. 9	Work. Ex. 10	Work. Ex. 11	Work. Ex. 12	Conv. Ex. 2	Work. Ex. 13	Work. Ex. 14
pipe outer diameter	D_0	67.0	67.0	67.0	67.0	67.0	170.0	170.0	170.0
pipe inner diameter	d_0	23.0	23.0	23.0	23.0	23.0	55.0	55.0	55.0
rod diameter	d	19.0	6.0	10.8	13.3	21.0	45.0	25.0	50.0
pipe inner/outer diameter ratio	d_0/D_0	0.34	0.34	0.34	0.34	0.34	0.32	0.32	0.32
pipe outer diameter	D_1	65.7	54.0	55.2	56.9	59.2	167.0	128.0	149.5
pipe inner diameter (=rod diameter)	d_1	19.0	5.1	9.3	11.8	18.7	45.0	19.7	44.4
pipe inner/outer diameter ratio	d_1/D_1	0.29	0.09	0.17	0.21	0.32	0.27	0.15	0.30
pipe outer diameter	D_2	44.0	44.0	44.0	44.0	44.0	60.0	60.0	60.0
pipe inner diameter (=rod diameter)	d_2	12.7	4.2	7.4	9.1	13.9	16.2	9.2	17.8
pipe inner/outer diameter ratio	d_2/D_2	0.29	0.09	0.17	0.21	0.32	0.27	0.15	0.30
ratio of pipe inner/outer diameter ratios	$\dfrac{(d_0/D_0)}{(d_1/D_1)}$	1.19	3.62	2.03	1.66	1.08	1.20	2.11	1.09
initial stretching position to integrated position	L_1	0	77	62	54	32	0	140	94
integrated position to final stretching position	L_2	85	138	121	108	125	400	270	271
ratio of distance to integrated position over total distance	$L_1/(L_1+L_2)$	0.00	0.36	0.34	0.33	0.20	0.00	0.34	0.26
pipe pressure reduction level (kPa)		100.0	13.3	13.3	13.3	13.3	100.0	13.3	13.3
heating temperature of stretching furnace (°C)		2250	2250	2250	2250	2250	2250	2250	2250
feed rate of pipe into furnace (mm/min)		10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
draw rate of stretched preform (mm/min)		22.3	20.6	21.1	21.4	22.7	77.5	73.6	78.8
bubbles in preform (per 100mm of preform)		0	1	1	0	1	0	0	1
mode field eccentricity amount of optical fiber (μm)		1.41	0.49	0.44	0.21	0.19	2.22	0.42	0.28

FIG. 6

FIG. 7

10/018369
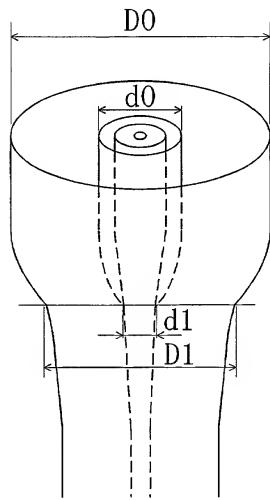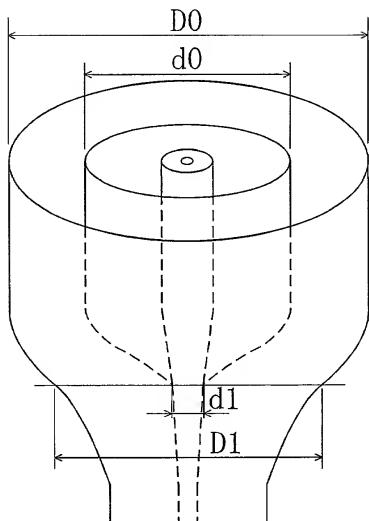
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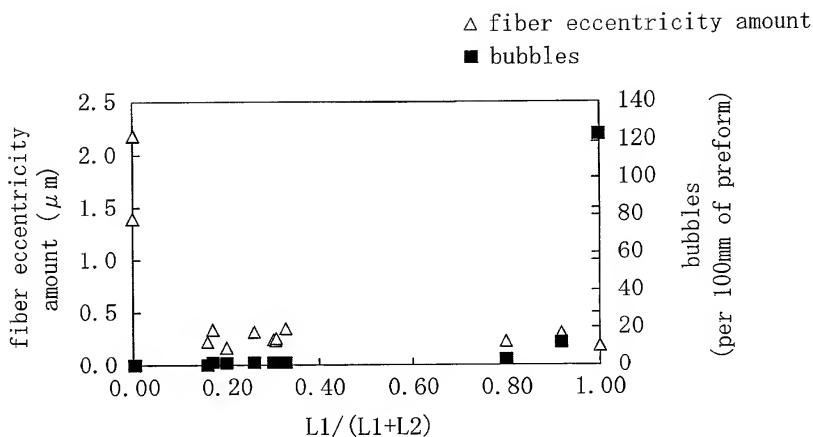
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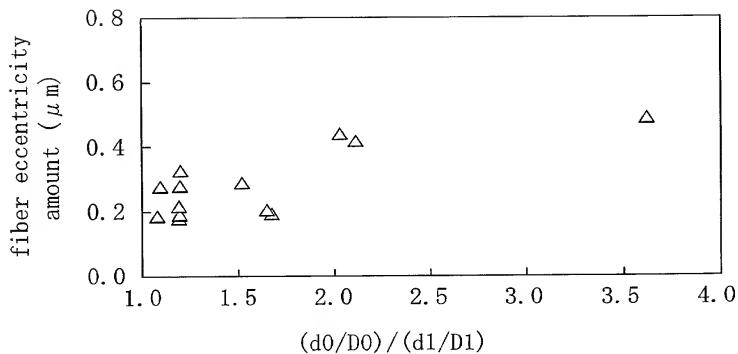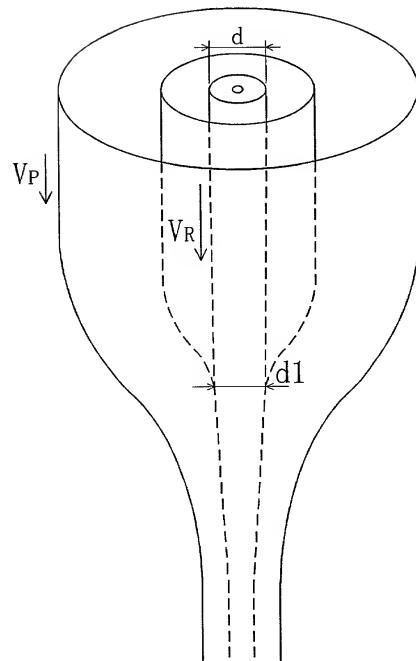
FIG. 10

FIG. 11
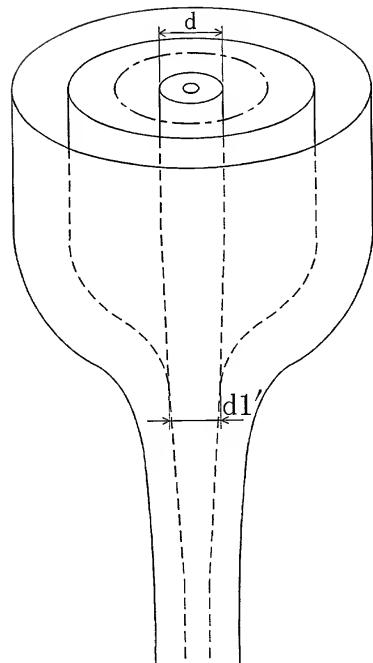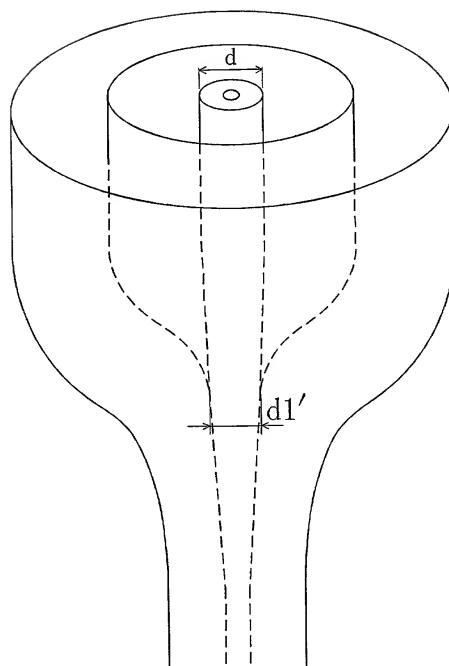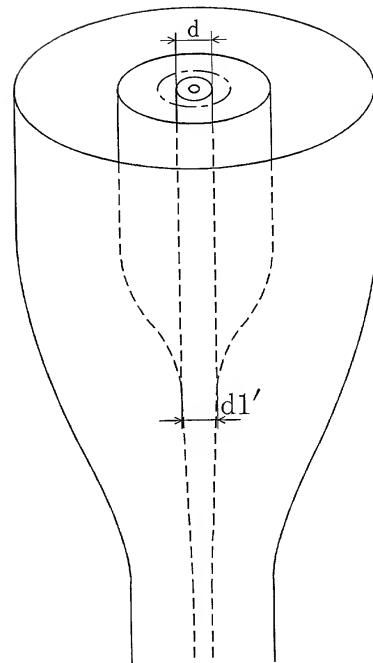
FIG. 12

FIG. 13

FIG. 14
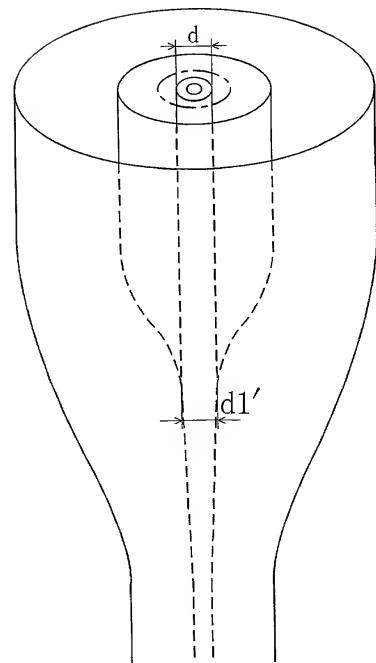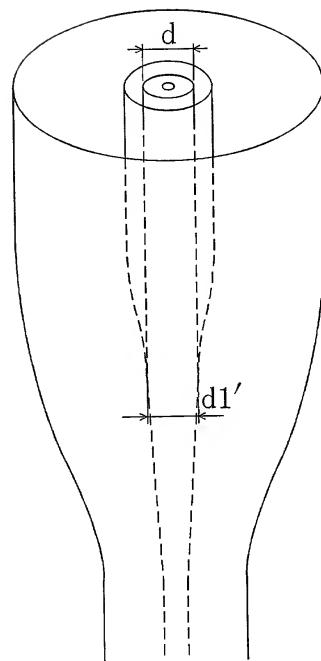
FIG. 15

FIG. 16

item	variable	unit	Work.Ex. (corresponds to FIG. 10)	Comp. Ex. 1 (corresponds to FIG. 13)	Comp. Ex. 2 (corresponds to FIG. 12)	Comp. Ex. 3 (corresponds to FIG. 15)
VAD rod outer diameter	d	(mm)	32.0	32.0	48.0	48.0
core diameter		(mm)	8.65	8.65	12.47	12.15
VAD rod C/C			3.70	3.70	3.85	3.95
pipe inner diameter		(mm)	53.0	53.0	70.0	55.0
clearance		(mm)	10.5	10.5	11.0	3.5
rod feed rate	V_R	(mm/min)	18.5	10.0	10.0	10.0
pipe feed rate	V_p	(mm/min)	10.0	10.0	10.0	10.0
pipe outer diameter		(mm)	168.5	168.5	189.0	175.1
(rod/pipe) feed rate ratio	V_R/V_p		1.85	1.0	1.0	1.0
outer diameter at integrated position			115.4	107.2	128.0	122.8
rod diameter at integrated position	d1	(mm)	30.3	—	—	—
rod diameter at integrated position	d1'	(mm)	—	21.0	33.8	34.1
completed preform C/C			14.1	18.9	14.6	14.2
target preform C/C			14.2	14.2	14.4	14.4
cut-off wavelength		(μm)	1.270	1.700	1.298	1.266
bubbles in preform	(per 100 mm length of preform)		0	0	0	67
mode field eccentricity amount of optical fiber		(μm)	0.25	unknown	1.22	0.24

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY (Includes Reference to PCT International Applications)	Attorney Docket No:

As a below named inventor, I hereby declare that:

My residence post office address and citizenship are as stated below next to my name,

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

METHOD FOR MANUFACTURING AN OPTICAL FIBER PREFORM

the specification of which (check only one item below):

[ ] is attached hereto.

[ ] was filed as United States application

        Serial No.
        on
        and was amended
        on _____ (if applicable).

[X] was filed as PCT international application

        Number PCT/JP00/04071
        on   June 21, 2000
        and was amended under PCT Article 19
        on _____ (if applicable).
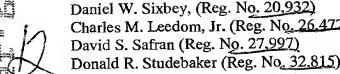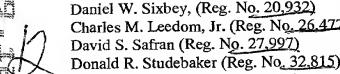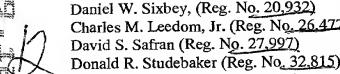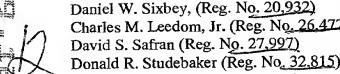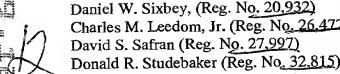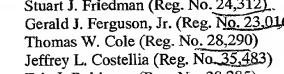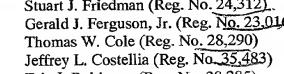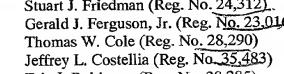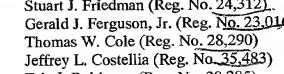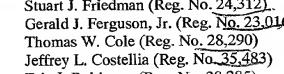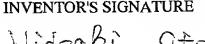
I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate or of any PCT international applications(s) designating at least one country other than the United States of America listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed:

PRIOR FOREIGN/PCT APPLICATION(S) AND ANY PRIORITY CLAIMS UNDER 35 U.S.C. 119:

COUNTRY	APPLICATION NUMBER	DATE OF FILING (day, month, year)	PRIORITY CLAIMED UNDER 35 USC 119
Japan	11-174954	22/06/1999	[X] YES [ ] NO
Japan	11-190517	05/07/1999	[X] YES [ ] NO
			[ ] YES [ ] NO
			[ ] YES [ ] NO
			[ ] YES [ ] NO

C00-5-097451

COMBINED DECLARATION FOR PATENT APPLICATION AND POWER OF ATTORNEY	Attorney Docket No:
(Includes Reference to PCT International Applications)	

I hereby claim the benefit under Title 35, United States Code, § 119(e) or § 120, as applicable of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56 which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application:

PRIOR U.S. APPLICATIONS OR PCT INTERNATIONAL APPLICATIONS DESIGNATING THE U.S. FOR BENEFIT UNDER 35 U.S.C. 120:

U.S. APPLICATIONS		STATUS *(Check one)*		
U.S. APPLICATION NUMBER	U.S. FILING DATE	PATENTED	PENDING	ABANDONED

PCT APPLICATIONS DESIGNATING THE U.S.					
PCT APPLICATION NO.	PCT FILING DATE	U.S. SERIAL NUMBERS ASSIGNED *(if any)*			

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. *(List name and registration number)*

Daniel W. Sixbey, (Reg. No. 20,932)
Charles M. Leedom, Jr. (Reg. No. 26,477)
David S. Safran (Reg. No. 27,997)
Donald R. Studebaker (Reg. No. 32,815)
Tim L. Brackett (Reg. No. 36,092)
Robert M. Schulman (Reg. No. 31,196)

Stuart J. Friedman (Reg. No. 24,312)
Gerald J. Ferguson, Jr. (Reg. No. 23,016)
Thomas W. Cole (Reg. No. 28,290)
Jeffrey L. Costellia (Reg. No. 35,483)
Eric J. Robinson (Reg. No. 38,285)
Thomas M. Blasey (Reg. No. 33,475)

Send Correspondence to: Nixon Peabody LLP 8180 Greensboro Drive, Suite 800 McLean, Virginia 22102	Direct Telephone Calls to: *(name and telephone number)* Eric J. Robinson (703) 790-9110

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

The undersigned hereby authorize any U.S. attorney or agent named herein to accept and follow instructions from __Maeda Patent Office__ as to any action to be taken in the Patent and Trademark Office regarding this application without direct communication between the U.S. attorney or agent and the undersigned. In the event of a change in the persons from whom instructions may be taken, the U.S. attorneys or agents named herein will be so notified by the undersigned.

FULL NAME OF SOLE OR FIRST INVENTOR **Hideaki ITO**	INVENTOR'S SIGNATURE Hideaki Ito	DATE December 11, 2001
RESIDENCE (City, State & Country) **Hyogo, Japan**		CITIZENSHIP **Japanese**
POST OFFICE ADDRESS (Complete Address including City, State & Country) **C/O Itami Works of MITSUBISHI CABLE INDUSTRIES, LTD., 3, Ikejiri 4-chome, Itami-shi, Hyogo 664-0027, Japan**		

Coo-5-097us1

FULL NAME OF SECOND JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
Masataka KON	Masataka Kon	December 11, 2001
RESIDENCE (City, State & Country) Hyogo, Japan		CITIZENSHIP Japanese
POST OFFICE ADDRESS (Complete Address including City, State & Country) C/O Itami Works of MITSUBISHI CABLE INDUSTRIES, LTD., 3, Ikejiri 4-chome, Itami-shi, Hyogo 664-0027, Japan		

FULL NAME OF THIRD JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
Takaharu KINOSHITA	Takaharu Kinoshita	December 11 2001
RESIDENCE (City, State & Country) Hyogo, Japan		CITIZENSHIP Japanese
POST OFFICE ADDRESS (Complete Address including City, State & Country) C/O Itami Works of MITSUBISHI CABLE INDUSTRIES, LTD., 3, Ikejiri 4-chome, Itami-shi, Hyogo 664-0027, Japan		

FULL NAME OF FOURTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
Nobusada NAGAE	Nobusada Nagae	December 11, 2001
RESIDENCE (City, State & Country) Hyogo, Japan		CITIZENSHIP Japanese
POST OFFICE ADDRESS (Complete Address including City, State & Country) C/O Itami Works of MITSUBISHI CABLE INDUSTRIES, LTD., 3, Ikejiri 4-chome, Itami-shi, Hyogo 664-0027, Japan		

FULL NAME OF FIFTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
RESIDENCE (City, State & Country)		CITIZENSHIP
POST OFFICE ADDRESS (Complete Address including City, State & Country)		

FULL NAME OF SIXTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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FULL NAME OF SEVENTH JOINT INVENTOR (if any)	INVENTOR'S SIGNATURE	DATE
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